Mixing of the CP Even and the CP Odd Higgs Bosons and the EDM Constraints

Tarek Ibrahim

Department of Physics, Faculty of Science, University of Alexandria, Alexandria, Egypt[1]

Department of Physics, Northeastern University, Boston, MA 02115-5000, USA

Abstract

The mixing among the CP even and the CP odd neutral Higgs bosons of MSSM by one loop induced effects in the presence of CP phases is investigated using three different mechanisms to satisfy the EDM constraints, i.e., a fine tuning of phases, a heavy sparticle spectrum, and the cancellation mechanism. It is shown that if a mixing effect among the CP even and the CP odd Higgs bosons is observed experimentally, then it is only the cancellation mechanism that can survive under the naturalness constraint.

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[1]:Permanent address

1   Introduction

Supersymmetric models with softly broken supersymmetry contain parameters which are in general complex and the phases associated with them are in general O(1). Such phases induce CP violation and contribute to the electric dipole moment of the electron and of the neutron and because the phases are O(1) such contributions are in general very large and in conflict with the experimental values[2]:

$$|d_e| < 4.3 \times 10^{-27} ecm, |d_n| < 6.3 \times 10^{-26} ecm. \tag{1}$$

There are several solutions suggested in the literature to avoid this conflict. One possibility suggested is that the phases could be small $O(10^{-3})$ while the SUSY spectrum is moderate[3]. This possibility, however, constitutes a fine-tuning. Another possiblity is that the EDMs are suppressed kinematically because of the heaviness of the sparticle masses that are exchanged in the loops of the EDMs operators[4]. This possibility puts the SUSY particle even beyond the reach of the Large Hadron Collider (LHC) and the heavy spectrum itself represents another fine tuning[5]. However, it was demonstrated that this need not to be the case and indeed there could be consistency with experiment even with large CP phases and a light spectrum due to an internal cancellation mechanism among the various contributions to the EDM[6]. The above possibility has led to considerable further activity and the effects of large CP phases have been studied in different phenomena[7]. There are other possibilities suggested in the literature to overcome the EDM problem which consists of using a mixture of the previous two scenarios[8]. As an example of a mixed solution is the one with non-universal trilinear coupling A_f (f=1,2,3). This scenario requires the phase of μ to be fine tuned to $O(10^{-2})$ or less, $phase(A_f) = (0, 0, phase(A_3))$ and the gluino mass to be heavy. Thus some phases of the theory are fine tuned and others are of O(1). To suppress the effects of these selected phases one has to push the corresponding masses up.

The cancellation mechanism opens a window of physics with large CP phases and a light SUSY spectrum. Analyses have been carried out to investigate the effects of CP phases on dark matter, on $g_\mu - 2$, on proton lifetime and on other low energy processes. One sector of relevance to us here is the neutral Higgs sector. It was pointed out in Ref. [9] that the presence of CP phases in the soft SUSY breaking sector will induce CP effects in the neutral Higgs sector allowing a mixing of the CP even and the CP odd states. Effects of mixings arising from

the exchange of the top-stops and bottom-sbottoms were computed in Ref.[10]. Additional contributions from the chargino, the W and the charged Higgs exchange loops were studied in Ref. [11].

In this paper we use the CP properties of the neutral Higgs bosons as an experimental probe to compare the three main solutions to EDM problem. The solutions of mixed type will not be considered here in details since their behaviour could be inferred from the main scenarios. We show that among the three scenarios, the cancellation mechanism has somewhat of a unique position in that it is the favored solution to the EDM problem if the MSSM Higgs bosons are discovered and are found to be admixtures of CP even and CP odd states.

To evaluate the radiative corrections to the Higgs boson masses and mixings we use the effective potential approximation

$$V = V_0 + \Delta V \tag{2}$$

where V_0 is the tree-level potential and ΔV is the one loop Coleman-Weinberg correction

$$\Delta V = \frac{1}{64\pi^2} Str(M^4(H_1, H_2)(log\frac{M^2(H_1, H_2)}{Q^2} - \frac{3}{2}) \tag{3}$$

with $Str = \sum_i C_i(2J_i + 1)(-1)^{2J_i}$ where the sum runs over all particles with spin J_i and $C_i(2J_i + 1)$ counts the degrees of the particle i, Q is the running scale and $H_{1,2}$ are the SU(2) Higgs doublets with non vanishing vacuum expectation v_1 and v_2:

$$(H_1) = \begin{pmatrix} H_1^0 \\ H_1^- \end{pmatrix} = \frac{1}{\sqrt{2}} \begin{pmatrix} v_1 + \phi_1 + i\psi_1 \\ H_1^- \end{pmatrix}$$
$$(H_2) = \begin{pmatrix} H_2^+ \\ H_2^0 \end{pmatrix} = \frac{e^{i\theta_H}}{\sqrt{2}} \begin{pmatrix} H_2^+ \\ v_2 + \phi_2 + i\psi_2 \end{pmatrix} \tag{4}$$

We consider here the contributions from the top-stop, and the bottom-sbottom and from the W-charged Higgs-chargino sector exchange. The mass squared matrix of the neutral Higgs bosons is defined by

$$M_{ab}^2 = (\frac{\partial^2 V}{\partial \Phi_a \partial \Phi_b})_0 \tag{5}$$

where Φ_a (a=1-4) are defined by

$$\{\Phi_a\} = \{\phi_1, \phi_2, \psi_1, \psi_2\} \tag{6}$$

and the subscript 0 means that we set $\phi_1 = \phi_2 = \psi_1 = \psi_2 = 0$. We introduce a new basis $\{\phi_1, \phi_2, \psi_{1D}, \psi_{2D}\}$ where ψ_{1D}, ψ_{2D} are defined by

$$\psi_{1D} = \sin\beta\psi_1 + \cos\beta\psi_2$$
$$\psi_{2D} = -\cos\beta\psi_1 + \sin\beta\psi_2 \tag{7}$$

and where $\tan\beta = \frac{v_2}{v_1}$. In this basis the field ψ_{2D} decouples from the other three fields and is a massless state (Goldstone field). The Higgs $(mass)^2$ matrix M_{Higgs}^2 of the remaining three fields is given by

$$M_{Higgs}^2 = \begin{pmatrix} M_Z^2 c_\beta^2 + M_A^2 s_\beta^2 + \Delta_{11} & -(M_Z^2 + M_A^2)s_\beta c_\beta + \Delta_{12} & \Delta_{13} \\ -(M_Z^2 + M_A^2)s_\beta c_\beta + \Delta_{12} & M_Z^2 s_\beta^2 + M_A^2 c_\beta^2 + \Delta_{22} & \Delta_{23} \\ \Delta_{13} & \Delta_{23} & (M_A^2 + \Delta_{33}) \end{pmatrix} \tag{8}$$

where $(c_\beta, s_\beta) = (\cos\beta, \sin\beta)$. The detailed structure of the elements in the above matrix is given in Ref. [11].

We note that the basis fields $\{\phi_1, \phi_2, \psi_{1D}\}$ of matrix (8) are the real parts of the neutral Higgs fields and a linear combination of their imaginary parts as displayed in Eq. (4) and so these basis fields are pure CP states. Thus $\phi_{1,2}$ are CP even (scalars) and ψ_{1D} is CP odd (a pseudoscalar). What we are interested here is the mixing between the CP even and the CP odd Higgs states in the eigen vectors of Eq. (8) and this mixing is governed by the off diagonal elements Δ_{12} and Δ_{23}. These can be written in the form

$$\Delta_{12,23} = A_{12,23}\sin\gamma_t + B_{12,23}\sin\gamma_b + C_{12,23}\sin\gamma_2 \tag{9}$$

where A, B and C are functions of the masses, of couplings, and of other SUSY parameters such as $\tan\beta$, etc., and $\gamma_{t,b,2}$ are linear combination of the CP phases and are given by

$$\gamma_t = \alpha_{A_t} + \theta_\mu, \quad \gamma_b = \alpha_{A_b} + \theta_\mu, \quad \gamma_2 = \xi_2 + \theta_\mu, \tag{10}$$

where α_{A_f} is the phase of A_f, θ_μ is the phase of μ parameter in the superpotential and ξ_2 is the phase of the gaugino mass m_2. In the limit of vanishing CP phases the matrix elements Δ_{12} and Δ_{23} vanish and thus the Higgs $mass^2$ matrix factors into a 2×2 CP even Higgs matrix times a CP odd element. From the structure of the matrix we see that the physical Higgs fields (the mass eigen states) have mixings between their CP even and their CP odd components and these mixings are induced purely by the existence of CP phases. Diagonalizing the M_{Higgs}^2 matrix

$$RM^2R^T = diag(m_{H_1}^2, m_{H_2}^2, m_{H_3}^2) \tag{11}$$

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one can calculate the percentage of the CP even components $\phi_{1,2}$ and the CP odd component ψ_{1D} of the three physical fields $H_{1,2,3}$. We order the eigen values so that in the limit of no mixing between the CP even and the CP odd states one has $(m_{H_1}, m_{H_2}, m_{H_3}) \rightarrow (m_H, m_h, m_A)$ where m_H is the mass of the heavy CP even state, m_h the mass of the light CP even and m_A is the mass of the CP odd Higgs in MSSM when all CP phases are set to zero. The similarity of the dependence on $\sin(SUSY phases)$ of the mixing matrix elements $\Delta_{12,23}$ and of the EDMs[4, 6, 7] is striking and indicates that there is a strong correlation between these two physical phenomena i.e. fermions of the theory possess EDMs and the neutral Higgs sector of the theory consists of non-pure CP states.

2   EDM and Higgs mixings analysis

We begin with a brief discussion of the EDMs of the electron and of the neutron. For the case of the electron we have that the electric dipole moment operator has only two components, i.e., the loop contribution from the chargino and from the neutralino . For the neutron EDM, we have three operators, the chromoelectric dipole moment , the electric dipole moment and the purely gluonic dimension six operator. The chromoelectric and the electric operators each have three components arising from the chargino, the neutralino and the gluino exchange loops. In addition to the above, there are two loop graphs[12] which contribute to the EDMS and have been included in the present analysis. However, it turns out that in essentially all regions of the parameter space investigated, the effects of the two loop contributions is very small.

For the general analysis in MSSM the number of parameters that are involved in the EDM and in the Higgs mixings is rather large. For the purpose of numerical study we confine ourselves to a constrained set consisting of: $m_0, m_{\frac{1}{2}}$, m_A, $|A_0|$, $\tan\beta$, θ_μ, α_{A_0}, ξ_1, ξ_2 and ξ_3. (For definition of the parameters see Refs.[6] and [11]). Using this parameter set we generate the sparticle masses at low energy starting at the GUT scale and evolving them down to the electroweak scale using renormalization group analysis. The parameter μ in the superpotential is to be evaluated using the constraint of radiative breaking of the electroweak symmetry.

In addition to the masses of sparticles and CP phases that affect the magnitude of the EDMs and the Higgs mixings, $\tan\beta$ has a large effect on the EDMs and also plays a crucial role in Higgs mixings as will be seen later. In Fig.1 and Fig.2 we show the $\tan\beta$ dependence of the different components of the electron and of the

neutron EDMs respectively. The figures show that the magnitudes of the electron and of the neutron EDM generally increase as $\tan\beta$ increases. For the case of the electron in Fig. 1 this behavior can be easily understood since the chargino component has a factor of $\frac{1}{\cos\beta}$ which grows as $\tan\beta$ increases and also there is another weaker dependence on $\tan\beta$ coming from the diagonalizing matrices of the chargino mass matrix but the net effect of both factors is to increase the chargino contribution with $\tan\beta$ as shown by the solid curve of Fig. 1. The large terms in the neutralino contribution are proportional to $\tan\beta$ coming from the elements of the matrix that diagonalizes the selectron $mass^2$ matrix. In comparison the contribution which comes from the elements of the matrix that diagonalizes the neutralino mass matrix produces only a weak dependence on $\tan\beta$. The neutralino contribution dependence on $\tan\beta$ is shown by the dashed curve of Fig. 1. Thus together the chargino and the neutralino contributions exhibit a dependence on $\tan\beta$ so that their total contribution increases with increasing $\tan\beta$. For the neutron case, we have contributions from the up quark and from the down quark. The up and down quarks have different $\tan\beta$ dependences. In the electric and the chromoelectric dipole moment operators the up quark contribution decreases as $\tan\beta$ increases while the down quark contribution increases. However, the down quark contribution dominates and thus the contribution of these two operators is an increasing function of $\tan\beta$ as shown by the solid and dotted with squars curves of Fig. 2. The gluonic operator has top-stop vertex in its two loop diagrams and thus has a term of $\cot\beta$ that decreases as $\tan\beta$ increases but it has also a bottom-sbottom vertex that contributes a linear dependence on $\tan\beta$. Thus d^G has a more complicated dependence on $\tan\beta$ as shown by the dashed curve of Fig. 2, where the sbottom contribution is larger in that area of parameter space. However, unless there are large cancellations between the electric and the chromoelectric operators the contribution from the gluonic operator is relatively small. As a result the neutron EDM is also an increasing function of $\tan\beta$.

We discuss now the Higgs mixing. We use the matrix elements R_{ij} of the diagonalizing matrix R in Eq. (11) to calculate the percentage of the CP even and the CP odd components of the physical Higgs fields in the neutral sector. In most of the parameter space investigated in Ref. [10] and [11], H_2, which limits to the CP even lightest Higgs as the CP phases vanish, develops almost no CP odd component and thus remains a pure CP even state. This result can be understood from the large difference in the magnitude between the two mixing terms Δ_{13} and

Δ_{23}. Thus MSSM with phases has one pure scalar Higgs field and the other states, i.e., H_1 and H_3, can have mixings. This mixing in H_1 and H_3 depends on the size of the CP phases and on $\tan\beta$, as demonstrated in Refs. [10] and [11]. The effect of $\tan\beta$ on the mixing is dramatic. This is shown in Fig. 3, where we have plotted the CP odd and the even components of H_1 as functions of $\tan\beta$. It is clear that even with large CP phases the CP odd component of H_1 is very small for $\tan\beta < 15$. However, this component can get very large as $\tan\beta$ gets large and it could become as much as 50% when $\tan\beta = 30$. The $\tan\beta$ dependence of the CP even-odd components of H_1 and H_3 can be understood from the matrix (8). Thus as $\tan\beta$ gets large, $\cos\beta$ becomes very small and $\sin\beta$ approaches 1 and the two heavy eigen masses $m^2_{H_1}$ and $m^2_{H_3}$ become approximately equal. This degeneracy is accompanied by large ϕ_1 and ψ_{1D} components in the linear combination structure of the two eigen states H_1 and H_3. The analysis of mixing of CP even-odd mixing in H_3 is exactly the same as for H_1 except that the components ϕ_1 and ψ_{1D} are interchanged in the linear combinations that appear in H_1 and H_3.

We explore now the different scenarios for solving the EDM problem and investigate the behavior of the Higgs mixings in each. The relevant variables here are the sparticle masses, α_{A_0}, θ_μ and ξ_i with $i = 1, 2, 3$ and $\tan\beta$.

Table 1: **EDMs and CP structure of H_1 for** $|A_0| = 2$, $m_A = 500$

$(case)\,\tan\beta, m_0,\, m_{\frac{1}{2}},$ $\xi_1,\, \xi_2, \xi_3, \theta_\mu,\, \alpha_{A_0},$	$d_e,\, d_n$	$CP-even,\, CP-odd$
$(1)2, 500, 400,$ all phases $= 10^{-2}$	$-7.4 \times 10^{-28},\, -3.1 \times 10^{-26}$	99.999%, .001%
$(2)30, 500, 400,$ all phases $= 10^{-3}$	$-1.3 \times 10^{-27},\, -4.0 \times 10^{-26}$	99.999%, .001%
$(3)5, 4000, 1200,$ all phases $= 10^{-1}$	$-6.2 \times 10^{-28},\, -3.8 \times 10^{-26}$	99.996%, .004%
$(4)5, 5000, 2240,$ $-2., -.3, .5, -.4, .4$	$1.1 \times 10^{-27},\, 2.7 \times 10^{-26}$	99.86%, .14%
$(5)30, 5000, 2240,$ all phases $= 10^{-2}$	$-2.2 \times 10^{-28},\, -9.5 \times 10^{-27}$	99.996%, .004%
$(6)30, 9500, 3600,$ $-2., -.3, .5, -.4, .4$	$2.2 \times 10^{-27},\, 6.2 \times 10^{-26}$	93.7%, 6.3%

These three scenarios to solve the EDM problem are the fine tuning of phases,

the heavy sparticle spectrum, and the cancellation mechanism. The first scenario for the EDM suppression assumes that the sparticles could have moderate masses while the CP phases are very small. An analysis of this scenario is given in cases 1 and 2 of Table. 1. Here the CP even-odd mixing in H_1 is small for both small $\tan\beta$ (case 1) and large $\tan\beta$ (case 2) which is expected since the CP phases are small.

In the second scenario with heavy sparticle spectrum the CP phases and $\tan\beta$ could be either small or large giving rise to four possibilities, i.e.,(1) CP phases small-$\tan\beta$ small, (2) CP phases large-$\tan\beta$ small, (3) CP phases small- $\tan\beta$ large, and (4) CP phases large- $\tan\beta$ large. We display these four possibilities as the cases 3, 4, 5 and 6 of Table.1. For case 3 where phases are small and for case 4 where phases are large, we see that EDMs constraints are satisfied while there is no mixing in the structure of the H_1 field. This field is almost a pure scalar which is due to the smalleness of $\tan\beta$. It is clear here that $\tan\beta$ is a crucial parameter in the Higgs mixing. For case 5 the mixing is also negligible although $\tan\beta$ is large and that is because the other important parameters here for mixing to occur i.e the CP phases, are small. So from the analysis of the three cases 3, 4 and 5 of Table.1, we find that one must have both $\tan\beta$ and CP phases large for the mixing in the Higgs sector to be observable. For case 6 where we choose both the phases and $\tan\beta$ to be large we find that the H_1 state is a mixed state. We notice that the sparticle masses involved here are very heavy and as an exmple the corresponding gluino mass for case 6 is 10.2 TeV. The values of m_0 and $m_{1/2}$ are the lower bound of these masses for EDMs to be suppressed below the experimental limit. The CP odd percentage of H_1 is 6% and to have more mixing, we have to make $\tan\beta$ larger and correspondingly also push the masses up to accommodate the EDM constraints. Thus for a sizable mixing to occur in the second scenario we must have CP phases and as well as $\tan\beta$ to be large which pushes the SUSY spectrum in the several TeV region to satisfy the EDM constraints.

One may now consider scenarios which are mixtures of the above two types and investigate the CP composition of the neutral Higgs in these. We will consider here two examples, i.e., the flavour-off-diagonal scenario and the focus point scenario. In the flavour-off-diagonal scenarios[14], we have a zero phase for the μ parameter and for the gaugino masses, large phases α_{A_t} and α_{A_b} in the third family, and small phases for A_u and A_d generated by RG effects because of coupling with the third family. In this model, the operator d^G makes the dominant contribution in the

neutron edm and its magnitude is governed by the phases α_{A_t} and α_{A_b}. Between the two phases the effect of α_{A_t} on the Higgs mixing is larger than the effect of α_{A_b} due to the fact that the chargino and stop exchange loop contributions are larger than the sbottom exchange contributions. Nonetheless it is important to include both α_{A_t} α_{A_b} for a complete analysis of the EDM constraints. Having included the sbottom and stop contributions to d^G of the neutron, one finds that for large α_{A_b} and α_{A_t} phases, $\tan\beta$ should not get large since sbottom contribution in this case dominates and one needs to push gluino mass up to higher values. So if we have a reasonable range of gluino masses, we find that this model gives us a case for moderate $\tan\beta$ and large phases which is a more complicated version of case 4 in Table. 1, and in this type of models, the neutral Higgs bosons are almost pure CP states. For the case where the gluino mass is very large $\tan\beta$ could get larger and in this circumstance the neutral Higgs bosons start to have a mixed CP structure. In focus point scenario models one can have sfermions masses of the first two generations in the multi-TeV region without affecting the fine tuning parameter of electroweak symmetry breaking. Here we can have moderate phases consistent with EDM constraints. However for $\tan\beta > 10$ [8] one cannot satisfy the experimental limits without assuming unnaturally small phases angles. So here also we have moderate $\tan\beta$ and large phases. Thus in this scenario also, the neutral Higgs bosons would be almost pure CP states.

Finally, we turn to the third possibility where one has moderate size masses and large phases which is normally excluded by the EDM constraints unless we have simultaneous cancellations among the different components of the electron and of the neutron EDMs. This region of the parameter space belongs to the the mechanism of EDM suppression by cancellations which we discuss now in detail. The algorithm to find a simultaneous cancellation of the electron and of the neutron EDM is straightforward. For the case of the electron one finds that the chargino component is independent of ξ_1 and d_e as a whole is independent of ξ_3. Thus for a given set of parameters except ξ_1 we start varying ξ_1 until we reach the cancellation for d_e since only one of its components (the neutralino) is affected by this parameter. Once the electric dipole moment constraint d_e is satisfied we vary ξ_3 which affects only d_n keeping all other parameters fixed. By using this simple technique one can generate any number of simultaneous cancellations. It is important to note that the cancellation mechanism also requires an adjustment of phases. The three important phases in EDM analysis ξ_2, ξ_3 and θ_μ are to be

significantly adjusted for the EDMs to simultaneously obey the constraints of the current experimental limits. One hopes that, eventually when one learns how supersymmetry breaks in string theory, such breaking will determine the phases and select the right mechanism for EDM suppression in SUSY theory. In the analysis of the cancellation mechanism given in ref.[13], EDMs were shown to obey a simple approximate scaling under the transformation $m_0 \to \lambda m_0$, $m_{1/2} \to \lambda m_{1/2}$ in the region where μ itself obeys the same scaling i.e, $\mu \to \lambda\mu$. In this scaling region, the chargino and the neutralino contributions for the electric dipole moment of the electron behave as $EDM \to \frac{1}{\lambda^2} EDM$ and thus d_e has the same scaling property. For the neutron case we have that both the electric dipole moment and the chromoelectric dipole moment operators have the same scaling i.e, $d^{E,C} \to \frac{1}{\lambda^2} d^{E,C}$ while the gluonic operator has the scaling property $d^G \to \frac{1}{\lambda^4} d^G$. Thus the scaling property of d_n is more complicated. However as λ gets large the contribution of d^G falls faster than d^E and d^C and in this case $d_n \to \frac{1}{\lambda^2} d_n$. In the scaling region knowledge of a single point in the MSSM parameter space where cancellation in the EDMs occurs allows one to generate a trajectory in the $m_0 - m_{1/2}$ plane where the cancellation mechanism holds and the EDMs are small. The cancellation mechanism can accommodate the EDM constraints with large CP phases, large or small $\tan\beta$, and a light sparticle spectrum which could be accessible at colliders. In Table.2 we display cases 1,2 and 3 where there is a large mixing. We note that for large $\tan\beta$ and large CP phases the individual components of the EDMs are large and the suppression here is due to cancellations. The mixing in H_1 reaches 44% in case 3 which is rather large. In Fig. 4, we generate the points of the curves out of points 1, 2 and 3 of Table. 2 by scaling where the EDMs constraints are satisfied. We have plotted the CP components of H_1 as functions of the scale λ. We note that the CP even-odd composition of H_1 is almost independent of scaling. This can be understood from the fact that the CP mixing is determined by the dimensionless matrix components R_{ij} which are almost scale independent.

Because of the $\tan\beta$ dependence of the EDMs explained above in Figs. 1 and 2, one finds that in regions where the gluonic operator contribution is small there could be another scaling. This scaling consists in multiplying $\tan\beta$ by a factor S which generates another point of cancellation out of a given one. One can also generate another point of cancellation even with gluonic contribution in the same order as the other operators if we choose a value of S close to 1. The important point here is that the CP even and the CP odd components are sensitive functions

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of $\tan\beta$. Point 4 is generated from point 1 by multiplying $\tan\beta$ with $S = \frac{4}{3}$. We note that the CP odd component is almost doubled while the magnitude of EDMs is still in the cancellation region.

We turn now to investigate the implications if MSSM Higgs bosons are discovered and are observed to possess a sizable CP even-odd mixing. In this case one must have both the CP phases large and a large $\tan\beta$. Now in this circumstance one can satisfy the EDM constraints either by having a sparticle spectrum in the several TeV region, which is discourgating from the point of view of their observation at colliders, or the cancellation mechanism which is favorable for the observation of sparticles at colliders. In the latter case the two Higgs bosons that have maximal mixing have degenerate masses for large $\tan\beta$ as discussed above. We wish to point out, however, that the cancellation mechanism remains a valid scenario even if the MSSM Higgs bosons are found and observed to be pure CP states as can be seen from case(5) in Table 2. In this region and because of strong dependence of mixings on phases some large phases could bring mixings to its minimum value.

Table 2: **EDMs satisfied and CP structure of H_1**

m_A, $\tan\beta$, m_0, $m_{\frac{1}{2}}$, $\|A_0\|$, ξ_1, ξ_2, ξ_3, θ_μ, α_{A_0},	d_e, d_n	$CP - even$, $CP - odd$
(1)$300, 30, 500, 400, 2,$ $-2, -.24, -.43, .3, -.4$	1.1×10^{-27}, 2.4×10^{-26}	88.4%, 11.6%
(2)$400, 40, 400, 490, 2,$ $-1.2, .57, -.09, -.4, .6$	2.1×10^{-27}, -2.1×10^{-26}	68.8%, 31.2%
(3)$300, 45, 600, 600, 2,$ $.1, -.45, -.28, .4, .5$	-3.2×10^{-27}, 2.7×10^{-26}	56.4%, 43.6%
(4)$300, 40, 500, 400, 2,$ $-2, -.24, -.43, .3, -.4$	2.3×10^{-27}, -1.8×10^{-26}	79.3%, 20.7%
(5)$300, 35, 650, 400, 1,$ $-1.5, 1.2, 1.22, 1.95, .7$	2.9×10^{-27}, -1.8×10^{-26}	99.94%, $.06\%$

In the analysis presented above we did not include the next to leading order corrections[15] in the Higgs mixings. However, inclusion of these refinements would not change very much the CP structure of the neutral Higgs bosons or the conclusions of this paper

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3   Conclusions

In this paper we have investigated the effects of CP phases, of $\tan\beta$ and of the sparticles masses on the electron and on the neutron EDMs and on the Higgs mixings. We have studied three main solutions to the EDM problem and their implications on the CP properties of the neutral Higgs bosons. It is found that unless we push the sparticle masses up to tens of TeV the only way out of the EDM problem is the cancellation mechanism if the neutral MSSM Higgs bosons are discovered with any observable CP mixings and one respects the naturalness constraints that the sparticle masses not lie in the several TeV range.

Figure Captions

Fig.1: Plot of $log_{10}|d_e|$ components as functions of $\tan\beta$; the solid curve represents chargino contribution and the dashed curve is the neutralino: the input parameters are $m_A = 300$, $m_0 = 500$, $m_{\frac{1}{2}} = 400$, $|A_0| = 1.0$, $\alpha_0 = 0.5$, $\xi_1 = 0.3$, $\xi_2 = 0.2$, $\xi_3 = 0.1$ and $\theta_\mu = .4$, where all masses are in GeV and all angles are in rad.

Fig. 2: Plot of $log_{10}|d_n|$ components as functions of $\tan\beta$; the solid curve represents electric dipole operator, the curve with squars is the chromoelectric operator and the dashed curve is the purely gluonic operator contribution for the same input parameters of Fig. 1.

Fig.3: Plot of the CP even component ϕ_1 of H_1 (solid curve) and the CP odd component ψ_{1D} of H_1 (dashed curve) including the stop, the sbottom and the chargino sector contributions as a function of $\tan\beta$ for the same inputs as in Fig.1.

Fig.4: . Plot of the CP even component ϕ_1 of H_1 (dashed curves) and the CP odd component ψ_{1D} of H_1 (solid curves) including the stop, the sbottom and the chargino sector contributions as a function of the scale λ. The inputs for the far left points of all cuves are those of points $1, 2, 3$ of Table. 2 and then scale both m_0 and $m_{1/2}$ as one goes to the right.

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